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# INTERNAL MOTION IN THE SPIRAL NEBULA MESSIER 33

## PRELIMINARY RESULTS

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One of the most interesting questions in astronomy concerns the relation of the spiral nebulae to the galactic system. Are they or are they not separate stellar systems comparable with our own? Especially during the last few years have many arguments been advanced both for and against. Real internal motions of the order indicated by the measures on Messier 101, communicated to these Proceedings in 1916,[1] would raise a strong objection to the "island-universe" hypothesis. If comparable with our own system, spiral nebulae would be so distant that no ordinary velocities of their constituent parts would yield measurable displacements in the short interval of a few years.

The measures on Messier 101 were, however, based principally on two plates taken by Mr. Ritchey at the 25-foot focus of the 60-inch reflector with an interval of only five years, and required confirmation before a general acceptance of the results could be expected. This was afforded in part by measures of three photographs of the same object taken at the Lick Observatory, which were kindly loaned by Director Campbell. Measures on Messier 81 also pointed in the same direction; while Lampland[2] found analogous motions for Messier 51 in 1916, and Kostinsky[3] in 1917.

Meanwhile another five years has elapsed, which would have doubled the interval for the 60-inch reflector photographs of Messier 101; but, unfortunately, bad weather during the spring made it impossible to obtain a satisfactory plate. In August, 1920, however, Mr. Duncan secured a fairly good photograph of another spiral, Messier 33, for which an excellent plate, taken by Mr. Ritchey in 1910, was also available. Messier 33 is, moreover, better adapted for such measures than Messier 101, on account of its numerous condensations and their close approach to star-

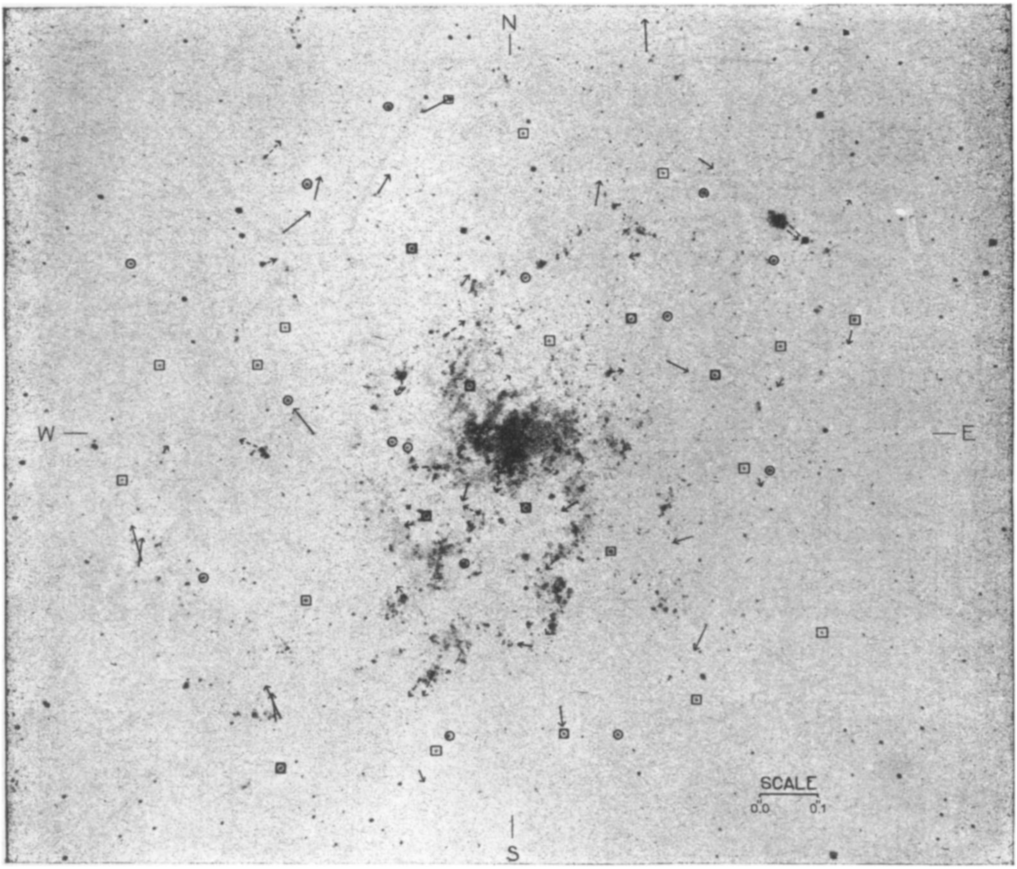
like appearance. For this same object two plates of short exposure, taken at the 80-foot focus of the 60-inch reflector in 1915 and 1920, were also available.

Both these pairs of plates have been measured with the monocular arrangement of the Zeiss stereocomparator. It has been shown that with temperature properly controlled this instrument is admirably adapted to such measures, because it allows the bisection in quick succession of corresponding points on the two photographs; the possibility of not bisecting a nebulous and asymmetrical point in the same way on both plates is thereby greatly reduced, if not wholly avoided. A note on the unreliability of the stereocomparator for accurate measures has recently been published by Kreiken;[4] but, as I have pointed out several times it is only necessary to keep the temperature of the room constant in order to secure good results with the Zeiss instrument. In our case the change in temperature during a series of measures can be kept within a few tenths of a degree. The influence of this variation is extremely small; but, as an extra precaution, we have adopted the plan of measuring the $n$ points, first in the order $1 \ldots\ldots n$, then in the order $n \ldots\ldots 1$. In this way practically all temperature effect can be eliminated, and it is easy to prove that the measures of the present series, which are of moderate length, cannot be affected by more than 10 or 12 per cent. For a series of several hundred points, whose measurement would take several days, the conditions are not so favorable, and in the present case it was thought best to await the completion of a new stereocomparator, now under construction in the instrument shop of the Observatory, in which the principal sources of trouble have been avoided, before undertaking the complete measurement of the plates.

For a preliminary discussion, 24 comparison stars and 23 nebulous points were selected on the plates taken at the 25-foot focus. When the measures had been finished, Mr. Seares was kind enough to call my attention to some photographs of Messier 33 taken by him with and without color-screens. A few years ago Seares found that the outer points of spiral nebulae are decidedly blue in color. A rough comparison of his plates showed that I had been fortunate in the choice of both comparison stars and nebular points. Of the first only three are blue, while of the latter all but two are decidedly blue; these two points have been omitted in the following discussion, since they may not belong to the nebula.

On the plates taken by me at the 80-foot focus all measurable points, a total of 89, were used. After the measures were finished I selected, with the help of the photographs taken by Mr. Ritchey and by Mr. Seares, 23 objects as comparison stars; these are all starlike in appearance and reddish in color. Ten points which are either very bright or very faint or for which the measures are uncertain were excluded. Of the remaining points, 22, including the centre, almost certainly belong to the nebula,

as they seem to be involved in the nebular knots and, with the exception of the centre, are decidedly blue. Fourteen points are probably nebular, being seemingly involved in nebulosity but not decidedly blue, or blue but not so clearly involved in the nebula. For 20 points it is quite uncertain whether or not they form part of the nebula.




Internal motions in the spiral nebula Messier 33. The dotted- and full-line arrows show the motions of points in the nebula derived from each of two pairs of photographs. The comparison stars are enclosed in small squares and circles.

For each set of plates the proper motions $\mu_\alpha$ and $\mu_\delta$ were derived for all the points measured with respect to the 24 and 23 comparison stars used. These motions for the points belonging to the nebula are presumably due partly to a translation of the nebula as a whole, and partly to internal motion. By a method analogous to that followed for Messier 101 the motion of translation of the nebula was found to be

$$\mu_\alpha = -0''.007, \ \mu_\delta = -0''.002.$$

The results found by subtracting these values from the motions of the nebular points are assumed to represent internal motions. In plate I those for the 30 points of the 25-foot focus plates are indicated by arrows with full lines and for the 22 very probable nebular points measured on the 80-foot focus plates by arrows with broken lines; the comparison stars of the first pair are enclosed in small squares, those of the second pair in circles.

A first inspection of the plate leaves us again in doubt as to whether we are dealing with a rotation of the nebula as a whole or with a motion along the arms of the spiral; upon further examination the latter motion seems to be more clearly indicated.

Resolving the motions into components perpendicular to and along the radius, we find the following results:

| | 25-FOOT FOCUS | 80-FOOT FOCUS |
|---|---|---|
| Right-handed | 23 or 77% | 17 or 81% |
| Left-handed | 7 or 23% | 4 or 19% |
| Outward | 18 or 60% | 15 or 71% |
| Inward | 12 or 40% | 6 or 29% |
| Mean tangential motion | +0″.020 | +0″.014 |
| Mean radial motion | +0″.006 | +0″.012 |

+ means right-handed and outward

Classifying the points according as they have a component of motion outward or inward along the arms of the spiral, we have the following results:

| | 25-FOOT FOCUS | 80-FOOT FOCUS |
|---|---|---|
| Motion outward | 28 or 93% | 18 or 86% |
| Motion inward | 2 or 7% | 3 or 14% |
| Mean outward motion | 0″.024 | 0″.021 |

Before discussing the possibility of an increase or decrease of motion with distance from the centre it will be necessary to measure a large number of additional points in the nebula, which is deferred for the present. The principal conclusion to be drawn from the present material is that here again we find motions analogous to those occurring in Messier 101, 81 and 51. In general they seem to be outward along the arms of the spiral.

In 1916 Pease published values for the radial velocity of the centre of Messier 33 and for the bright knot 10′ *nf* the nucleus. The two values differ by about 200 km./sec. Taking into account the probable inclination of the nebula with respect to the tangential plane, we can gain some

idea of the order of the parallax of the nebula by comparing Pease's results with those obtained from the present investigation; the corresponding parallax is about 0″.0005. The diameter of the nebula would be about 100 light-years and the individual points of the nebula would have absolute magnitudes of +1 and fainter.

If on the other hand we suppose the dimensions of Messier 33 to be comparable with those of the galactic system, its distance would be several million light-years; the motions indicated by the photographs would then represent velocities of the order of 150,000 to 300,000 km./sec., which, obviously, are extremely improbable. The internal motions in the spirals seem now to be well founded, and if time justifies this belief, they will accordingly afford a most important argument against the view that these nebulae are systems comparable with our galaxy.

[1] van Maanen, A., *Mt. Wilson Contr.*, No. 118, 1916; *Astrophys. J., Chicago, Ill.*, **44**, 1916 (210–228).

[2] *Amer. Astron. Soc. Publ.*, **3**, 1918 (206–207).

[3] *Monthly Notices, Lond.*, **77**, 1917 (233–234).

[4] *Observatory, Lond.*, **43**, 1920 (255–260).

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## *THE ATTACHMENT OF ELECTRONS TO NEUTRAL MOLECULES IN AIR**

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It is well known that the process of ionization in gases consists of the detachment of an electron from the molecules or atoms ionized. It has further been proved that in air at atmospheric pressure the carriers of negative electricity are neutral molecules[5,6] of the gas carrying an additional electron. These are called the normal ions. Now it is of interest to determine in what manner the electron liberated by the ionizing process attaches itself to a molecule to form an ion. For it is possible that an understanding of this process may help us to gain a picture of the surfaces of the molecules.

In air at atmospheric pressure the normal negative ions move with a velocity of 2 cm./sec. in unit electric field while the electrons have a mobility of about 200 cm./sec.[3,7] under the same conditions. Such a marked difference in the two types of carriers accordingly furnishes us an excellent means of investigating the above question as the ensuing analysis will show.

Let us assume that the electrons liberated from the plate $P$, figure 1, by ultraviolet light unite with gas molecules on their first impacts to form ions. Now let a second plate, $E$, connected to an electrometer be placed